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Guidelines (Considerations) to reduce environmental impacts of vessels. Results of PIANC INCOM Working Group 27

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RESULTS OF PIANC INCOM WORKING GROUP 27: "GUIDELINES TO REDUCE ENVIRONMENTAL IMPACTS OF VESSELS"

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ABSTRACT

Taking into account the increasing importance of nature conservation in operating inland waterways, the PIANC Inland Navigation Commission founded a new working group called *Guidelines to reduce environmental impacts of vessels*. The main task of this group was to address important direct impacts of shipping on the environment and to find solutions for reducing negative impacts as efficiently as possible.

The paper first provides an insight into the decision-making process of the group composed of civil and naval engineers and biologists. One of the main problems to be solved was to overcome the different ways of thinking and understanding of engineers and biologists. Because the report should be readable for both, the group decided to initially describe all the main impacts from an engineering as well as from an ecological point of view. This gave rise to so-called technical and ecological "fact files", looking on the one hand from the impact down to ecological endpoints and on the other hand from relevant ecosystems and their demands back to impacts, affecting selected representative species of fish and water plants.

Additionally possible mitigation measures will be discussed and assessed. Examples of effective mitigation measures are: modified ship design, fairway relocation, restrictions to navigation, e.g. reduced ship speed or engine power, if applicable only seasonal restrictions, technical measures such as conservative or alternative bank protection measures, relocated revetments, wave breakers etc. With this knowledge, the paper presents a simplified assessment procedure on how to check the ecological relevance of shipping impacts by taking the status of the water body, the vicinity of the impacts to critical values and the capabilities and restrictions of mitigation measures.

1. INTRODUCTION

Motivation for setting up Working Group 27

The need to address environmental issues regarding vessel impacts has become a necessity in evaluating, designing, improving and operating waterways for different reasons. One reason for this is the increasing importance of nature protection, especially in industrialised countries, in order to keep remaining natural resources alive in cases where inland navigation is expected to increase further in the future. This was one of the reasons for investigating vessel effects in detail in the Upper Mississippi pools. The outcome of these studies, realised mainly by the Engineering Research and Development Centre (ERDC) of the US Army Corps of Engineers, was one of the motives for creating the new InCom Working Group 27 (WG) *Guidelines to reduce environmental impacts of vessels* and also an important source of information for the report.

Another reason for taking into account environmental aspects in more detail is the changing legislative situation in the European Union such as the Water Framework Directive which requires waterways operators to fulfil tightened restrictions regarding ecology. In many cases environmental aspects can also go hand in hand with engineering and economical aspects, e.g. if alternative bank protection measures such as bioengineering are applied: this measure can help save construction and maintenance costs compared to traditional protection measures such as riprap.

Terms of reference (TOR) according to InCom instructions

In order to minimize potential impacts, enhance environmental opportunities, and provide an environmentally sustainable waterway system it is necessary to identify, quantify, and predict vessel effects and their potential ecological impacts. Right now many problems of inland waterway systems are related to the direct impact of vessel-generated waves and propeller scour, to mention just two aspects. The corresponding physical forces along with projected increases in traffic volume can produce severe ecological impacts. In several PIANC publications guidance is given on how to quantify ship waves or propeller jet velocities. However, due to the recent focus of studies on assessing the ecological impact of vessel traffic, WG 27 should expand its guidance and include state-of-the-art methods for describing, quantifying, and managing physical effects in more detail.

Specification of TOR and approach

The TOR defined above do not include those impacts coming from the preparation of the water bodies for navigation use such as training or damming up rivers in order to increase fairway depth or to construct a new canal. These indirect effects usually affect the ecosystems of waterways much more than the direct impacts to be considered by WG 27, but their consideration would exceed the respective PIANC report because of the variety of problems that would have to be considered. Nevertheless, given the fact that *development, extension* or *improvement* of waterways are rather the exception nowadays and that the *operation* of waterways is daily business, the *direct* effects of shipping, especially on the environment, and their mitigation are becoming increasingly important in order to enhance the acceptance of waterways as a transport system – which from a politico-economic point of view is the most efficient and, in our opinion, the most environmentally friendly transport mode compared to other competing transport modes.

Despite the fact that only direct impacts will be considered, what *needs* to be considered are the continuously changing boundary conditions as these give rise to typical questions to be answered for operation of our waterways. These mostly come from

- a changing fleet with a general trend towards larger and more powerful vessels; a changed cargo type with a tendency towards increased container transport not only in the maritime sector; modified permissions, e.g. allowing larger vessels, higher ship speeds and draughts, which is generally possible for new ships considering the enhanced safety equipment and also the improved navigability of these vessels,
- the necessity to adapt fairway dimensions and alignment to account for e.g. environmental aspects for taking care of sensitive areas, to account for a modified channel morphology, e.g. caused by erosion or sedimentation processes, or
- changing habitat properties, e.g. caused by eutrophication.

Other important impacts arise from maintenance measures for the purpose of ensuring navigability, e.g. dredging, causing above all a higher turbidity and probably a release of contaminated sediments into the water body. This also holds true for the infiltration of non-native species (aliens) into our waterways which can modify existing habitats much more than all the direct impacts stemming from moving vessels. For example, most of the total biomass in the River Rhine consists of one of these aliens currently known as the "killer shrimp", replacing native species. These impacts would also exceed the scope of this report, but are treated in several other reports and also by PIANC working groups and will therefore be neglected in the following.

Nevertheless, the subject of direct vessel impact is complicated enough due to

- the different water bodies to be considered, such as large free-flowing or dammed rivers with various water depths, flow velocities, bed and bank sediments, backwaters, marsh areas and corresponding habitats, especially in aquatic areas near the banks; lakes, canals and lagoons which vary mostly in their water depth, stage and flow velocity variability,
- the different vessel types ranging from large push tow units, cargo vessels of different sizes and draughts to recreational boats, having different hull shapes, speed ranges, propulsion systems and navigational aids, and
- the different impact types such as drawdown and return currents, secondary waves, propeller wash and scouring up to impacts caused by direct contact with the ship hull and the propellers, and related indirect effects, e.g. from induced sediment transport phenomena such as increased turbidity due to the resuspension of bed sediments.

For these reasons, it is almost impossible to give generally valid guidelines for *all* possible cases, and not even for the most relevant cases because, besides the impacts mentioned above, there is a huge variety of species living in and close to our waterways with their special habitats, depending on the location on our globe, the climate, bed and bank substrate, water quality etc.; so every impact problem generally requires an isolated case consideration. Accordingly the group members decided to call the report "*Considerations*" rather than *"Guidelines" to reduce environmental impacts of vessels*; and instead of giving *recommendations* they outline the *procedure how to find a solution* for a specific impact problem taking into account its unique boundary conditions instead of giving detailed instructions for selected cases. These considerations are based on a deep insight into the physics of vessel impacts (technical part of the report) and into the typical aquatic ecosystems and their properties (ecological part). This information will be collected in so-called ***fact files*** which form the backbone of the PIANC report; the structure of the report will follow two approaches:

The first (technical) approach, called ***"Top Down Consideration"***, covers direct vessel effects such as stranding of fish larvae due to water level drawdown of a moving vessel, over indirect effects such as ship-induced sediment transport that could lead to resuspension of contaminated bed sediments, up to the mortality of fish. This intercorrelation of different effects to be considered is called *impact cascade*. Based on the impact cascade the most important impacts are described in detail in the following fact files:

- *Ship Types* and *Propulsion Systems*
- *Drawdown, Primary Wave Field and Induced Flows*
- *Secondary Wave Field*
- *Propeller Jet and Scouring*
- *Order of Magnitude of Typical Impacts*

The last chapter summarises the information from the technical fact files and provides an idea of the typical magnitude of impacts. Although the numbers given can vary a lot from case to case, it is important to consider the results of several field investigations regarding this matter; they provide the basis for a table of *"typical peak values"* of impacts to be compared e.g. with tables of impact thresholds at which significant negative ecological impacts have to be expected or with tables of tolerable impacts of different mitigation measures, such as e.g. alternative bank protections. These tables are currently being worked out by WG 27 and will be referred to in the PIANC report to be published shortly.

One example of the technical fact file contents and of the way the information will be presented regarding turbidity caused by propeller wash will be described in detail in the next chapter.

- The second (ecological) approach, called ***"Bottom-up Consideration"***, covers the properties and needs of characteristic water bodies and their ecosystems. The habitats of plants living e.g. in the bank zone are adapted to a more or less constant water table. So even small changes in water level can affect the ecosystem of lakes more than in rivers with their typical water level fluctuations. Therefore impacts are ranked according to the type of waterways, but also according to taxa (species) groups. For this reason fact files will be given for every relevant aquatic habitat type, starting from plants, over invertebrates, fish, mammals, birds, up to amphibians and reptiles.

  From this, the above-mentioned threshold values of important impacts can be derived, giving an idea up to which level impacts should be dropped down, e.g. by appropriate mitigation measures, in order to avoid significant negative environmental effects. As mentioned above in the context of the table containing typical peak values of shipping impact, these thresholds can also vary widely from case to case. But the group's members prefer to have these numbers derived from a restricted number of existing experiences from European and North American channels rather than to give no information at all. It's the responsibility of the report readers to check whether the thresholds can be used in their specific case or not.

Both approaches, "Top Down" and "Bottom Up" with their detailed information and corresponding tables, can be used in the following to assess possible ecological risks caused by shipping.

The following steps need to be undertaken:

1. *Description and specification of impact problem, assessment area, and relevant potential impact sources:* The description should include the type and magnitude of the water body, its bed and bank sediments, relevant climatic conditions, water quality, ecosystems, their state ("heavily modified" up to "close to natural state"), navigation (existing, future), physical environment forces (existing, future), existing information from site investigations and literature etc. These items should be understood as reminders to be adjusted to the site-specific problem considered.
2. *Detailed consideration of the ecosystem on site, its relevant species affected and their sensitivities to impacts:* This means choosing representative species currently present in their ecosystems to be considered in detail which will be affected either directly or indirectly by navigation. Only the most severe effects and changes resulting from the proposed changes to navigation and shipping should be taken into account and only the most important direct or indirect impacts, leading to a reduction or destruction of the chosen species, should be considered in Step 3.
3. *Detailed evaluation of the significance of the chosen important impacts:* Every increase in water transport is likely to have a negative impact on the immediate environment, but it needs to be considered that this may not be significant as it may be more than offset by the wider environmental benefits of efficient transport.

Step 3 is called *"ecological relevance check"*. It is a roughly simplified approach reflecting only some chosen criteria. Because of this it was highly discussed in the working group during the whole process of report writing, especially between engineers and biologists; but the members agreed to recommend this approach because in every PIANC member country the legal situation for assessing ecological impacts is completely different and cannot be reflected in a PIANC report at all. Therefore the ecological relevance check cannot replace these different laws, but it can help identify the most important impact problem and its possible mitigation.

4. *Impact Reduction and Modification:* This step includes the assessment of the potential within the physical environment for managing the significant impacts, using mitigation measures and their effectiveness in the project area. It also includes the assessment of the risks, whether the measures taken will be effective or not, e.g. to limit the ship speed, taking account of the "human factor". The essence of the relevance check is shown in the following table, in which several criteria lead to the ecological significance level.

The essence of this procedure is Step 3 (relevance check), reflecting the criteria given in the following table:

System behaviour			**Significant increase from current conditions**	**Legal protection**	**Properties and corresponding qualifiers**								**Ecological impact significance**
Relevant direct / indirect impact	Threatened representative species	Affected part of the system		Internat., national or local protection of species / habitat in law	State of the corresponding ecosystem [1]	Importance of species or habitats [2]	Vicinity of impact to thresholds [3]	Duration and frequency of the impact [4]	Possibilities and limits of mitigation measures [5]	Percentage of affected area [6]	Effects on neighbouring ecosystems [7]	Main risks [8]	
Draw-down	Fish larvae	Bank zone	Already beyond threshold	No	Heavily modified	Ordinary	Close	Short but frequent	Creating pools, speed reduction	Total	No	"Human factor"	Low
	Fish larvae	Fairway		No									
	Fish larvae	...											
	Adult fish...												
	...												
Propeller hits	Adult fish												
	...			Yes									High
Resuspension from return currents													

1 heavily modified (1), modified (2), close to natural state (3) – in brackets possible weighting factors
2 common (0), locally rare (1), rare (2), "the last" (3)
3 far away (0), close (1), overtopped (2)
4 short/seldom with long intervening phases (0), long/frequent with short intervening phases (1), nationally rare (2), world rarity (3), "the last" (4)
5 possible, feasible and economical (1), effectiveness questionable and/or expensive (2)
6 small (0), average (1), nearly total (3)
7 no relevant negative effects (1), noticeable negative effects (2), severe negative effects (3)
8 low (1), average (2) or high (3)
9 nearly no negative effects, significant negative effects but avoidable, severe non-avoidable negative effects

Table 1: Checklist for ecological impact significance with examples of the case of a canal reach with deep draft vessels

First the system properties and behaviour need to be checked, including the relevant direct and indirect impacts, threatened representative species, and affected parts of the ecosystem. The next criterion concerns the state of the ecosystem, i.e. whether it is close to the natural state or heavily modified. Other criteria are the importance of species or habitats affected by the impact, the vicinity to threshold values, the duration and frequency of the impacts, the question whether mitigation measures are possible, feasible, and effective or not, the area affected, and whether there are negative effects on neighbouring ecosystems.

If the affected area is small, the frequency of impacts low, the present state of the ecosystem far from the natural state, and if only the usual species are affected, it is obvious that the *"ecological impact significance"* should be assessed as low. In contrast, if the impacts differ a lot from the threshold values and concern important ecosystems, and if they affect species on the red list, the ecological significance is high and mitigation measures should be taken if possible.

This "ecological impact significance", given in the last column of the table below, can be chosen according to weighting factors, depending on the system properties and on the relevance of each impact. To compare e.g. different reaches or possible variants, the relevant level factors could be summed up over all the impacts, species and parts of the system considered.

Because the chance of effective mitigation is a main criterion of the assessment procedure, it should be a main task of the PIANC report. Some examples of possible mitigation measures are given in the following table.

Mitigation measure		**High efficiency level → Low efficiency level**	**Most reduced impacts**
Navigation rules		Ship type permission, e.g. prohibition of pleasure boats	Hull and propeller contact to fish, noise, bank erosion
		Restrictions to engine power	Propeller scouring and resuspension
		Restricted draught	Return currents, primary waves
		Speed control	Wave attack on banks
		Mooring restrictions	Bank erosion by thrusters
		Increased distance from sensitive areas	Wave heights, wake wash, return currents, noise
Engineer-Ing Measures	Ship adaptation	Propulsion systems without jet deflection to channel bed or without jet splitting	Propeller jet and scour, resuspension, turbidity, bank erosion
		Ships fitted to the fairway dimensions	Primary waves and wake wash, return currents
		Ships with smaller wave heights	Bank erosion
		Passive bow rudders instead of bow thrusters or pump jets	Bed erosion and scouring, resuspension of bed sediments
	Protection of sensitive areas	Fairway adaptation (reduced dimensions, fairway relocation, especially increased distance from banks)	Wave attack on bed and banks, return currents, bank erosion
		Wave breakers in canals and lakes, e.g. to protect oldwaters	Secondary wave heights, drawdown driven outflow from oldwaters
		Direct erosion protection measures, e.g. groynes to protect bank in rivers	Bank erosion, return currents in bank zone
	Nature friendly protection	Bioengineering and biotechnical engineering, e.g. to protect channel banks	Loss of habitats, reduction of species
Compensation of affected or lost habitats		Reopening of adjacent oldwaters, side channels and oxbows	Loss of habitats, reduction of species
		Creating (artificial) new habitats, connected to the main channel (reservations)	Loss of habitats, reduction of species

Selected mitigation measures, their efficiency and most reduced impacts

In this context the group decided to describe typical measures in more detail, including

- engineering measures, e.g. direct (riprap, environment-friendly protections) or indirect (wave breakers, parallel dykes) bank protections, or connecting the impacted water body with side channels or pools with reduced impacts,
- navigation rules, e.g. limiting size and installed engine power of the vessels, limiting ship speed, increasing the distance between vessel and areas to be protected, seasonal restrictions to traffic, or
- adapted vessel and fairway design and adapted vessel speed.

It should be pointed out that if there is any realistic chance of influencing vessel design features, e.g. by means of licensing, one should take this chance because some modifications in ship design may provide an important contribution to mitigating negative vessel effects. To give one example: shifting engine power from one single propeller to several propellers, providing together the same thrust as one propeller alone, could reduce the near-bed flow velocities to about 30 % or the shear stress to 50 % in the case of two thrusters. This, in turn, can in many cases mean avoidance of scouring or resuspension.

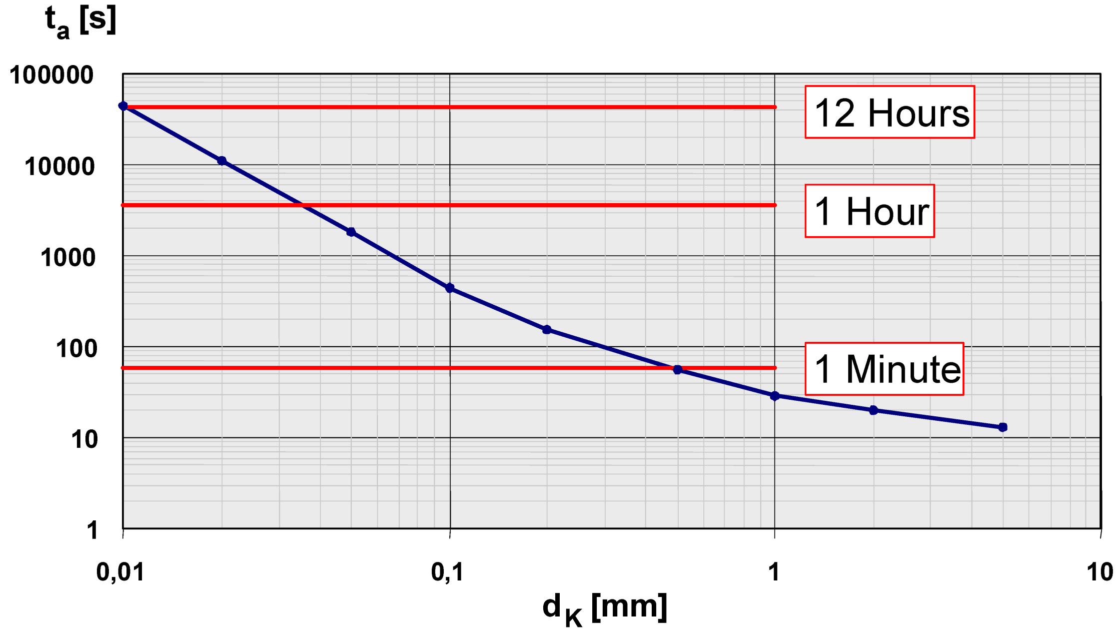
Also fairway relocation can significantly reduce impacts on sensitive areas if the distance from the fairway to the banks is increased. This is possible in many cases because modern ships usually have much better navigation aid devices which means they generally need a smaller fairway width.

In cases in which commercial navigation which induces the highest impacts, speed reduction is a key element in solving impact problems from return currents, drawdown and ship-generated stern waves, because these impacts increase roughly by the third power of the ship's speed. So a speed reduction of only 10 % could decrease the impacts by about 30 %. Nevertheless, as shown in the next chapter, speed reduction is not a solution in every case.

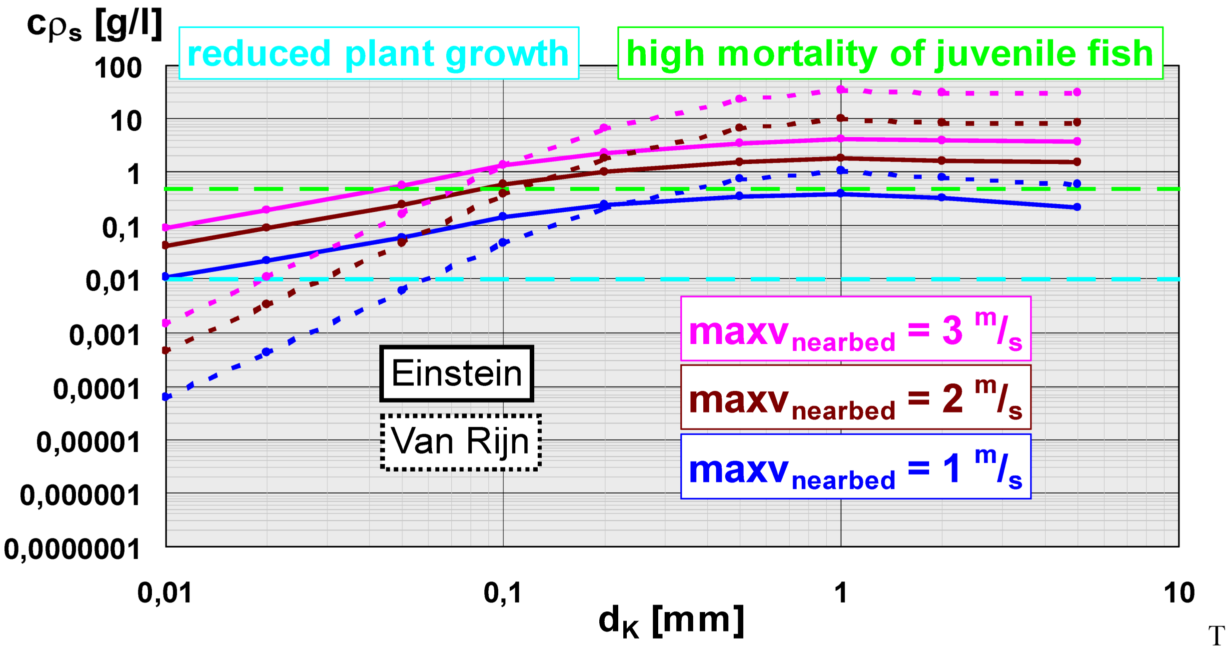
Additionally, two mitigation checklists will be provided. The first one shows the impacts that could be reduced most easily by typical mitigation measures – providing an idea of the efficiency of these measures too. This table is given see above. The second table starts from the impact and gives an idea of the most effective mitigation measures.

2. EXAMPLE FROM THE TECHNICAL FACT FILE “PROPELLER JET AND SCOURING”

The following example concerns a typical problem in large rivers such as the Mississippi: the turbidity caused by resuspended sediments induced by propeller wash. It will be explained using the following two graphs. The first graph shows how the settling time of a single grain of suspended material depends on the average grain size. It was drawn up using well-known formulae to describe sediment transport phenomena in rivers, assuming an initially uniform sediment concentration distribution over the water depth. This graph shows that a chosen grain size of about 0.1 mm, which is typical for lowland rivers, has a settling time of about 7 minutes. This means that, if the time period between two large push tow unit passages producing the resuspension is less than about 7 minutes, some bed material will permanently remain in suspension in the area behind the stern of the push tow and the water will stay turbid. If the period is much longer, and this is generally the case on the Mississippi river, there will be long gaps without any significant propeller induced turbidity and impacts are less probable. So the traffic density on the one hand and the grain size on the other hand are the key values to be considered as far as turbidity problems are concerned.



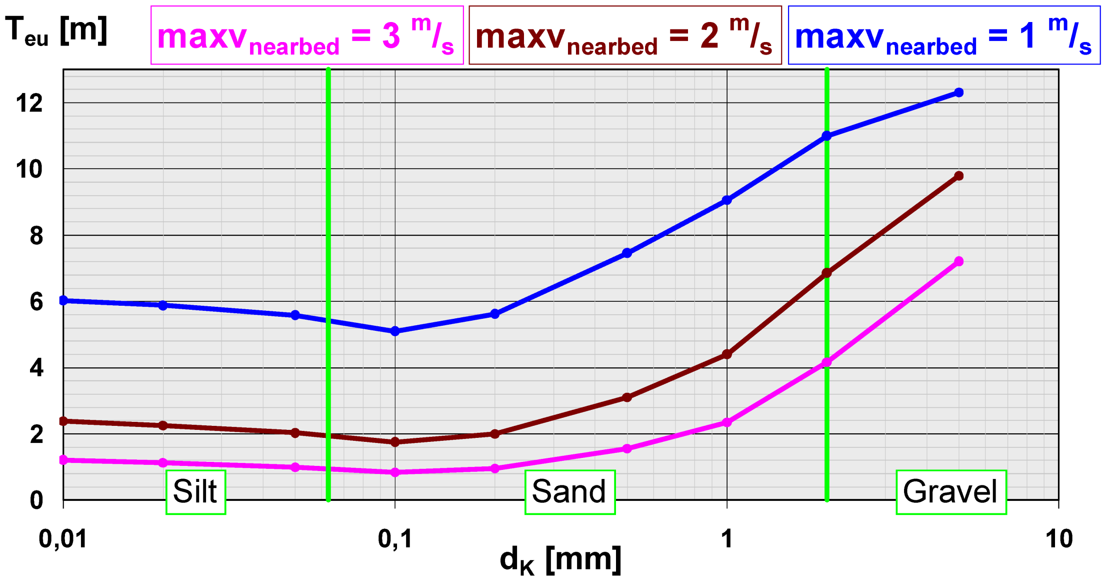
Settling time t_a as a function of grain size d_k for water depth 4 m



Depth-averaged sediment concentration $c\rho_S$ as a function of grain size d_k and near-bed flow velocity from propeller wash for water depth 4 m

The above graph shows calculated sediment concentrations for typical near-bed velocities from propellers between 1 m per second, which is typical for a fast moving modern cargo vessel, 2 m per second, which is typical for large tows, and 3 m per second, which can occur under manoeuvring conditions of large tows. The calculations were made using simplified approaches to account for boundary layer development on the river, taking the above-mentioned characteristic velocities as constant and using sediment transport relations of Einstein and Van Rijn.

The result is that even for very small grain sizes a threshold value for the sediment concentration of about 0.7 g/l, at which high mortality of juvenile fish can occur, will not be exceeded for all typical grain sizes between 0.01 mm and 10 mm in the case of a 1 m/s propeller wash. Correspondingly calculated euphotic depths (depth up to which plant growth can occur) which are shown in the next figure are higher than the assumed depth of about 4 m.



Euphotic depth T_{eu}, defined as 10 % of light remaining on the river bed and theoretically calculated by using the random shading of light of each grain, assuming a constant sediment concentration over the depth according to the figure above

So modern, fast moving vessels will probably produce a generally slight sediment concentration and turbidity, but if large tows are forced to drive under manoeuvring conditions, e.g. at bottlenecks with large flow velocities going slowly upstream, using nearly the maximum installed engine power, the euphotic depth could drop down to about 2 m corresponding to these theoretical considerations. So the maximum sediment concentration occurring immediately after the vessel passage and the corresponding euphotic depth highly depend on the power used, on the ship's speed, and on the grain size. So, if vessels can move fast, e.g. because the channel cross section is large and the flow velocities are low, the maximum near-bed velocities are lower and negative turbidity-related effects from bed material resuspension can be avoided. So reducing the ship speed in order to reduce impacts is not a solution in all cases, e.g. if the engine power used is not restricted simultaneously or cannot be reduced for other reasons such as ensuring safety and ease of shipping. So mitigation measures very much depend on the local situation.

3. CONCLUSIONS

As shown especially by the example of the technical fact file, a special impact problem to be solved in operating waterways highly depends on answering the following questions, defining the necessity whether measures should be taken or not, and defining the appropriate choice of mitigation measures:

1. *What are the reasons for reducing shipping impacts?*
   These could be damage on bank protection measures, changing permissions, a changing fleet, or increased traffic. Further reasons are the changing environmental conditions such as the eutrophication of the channel or a new legislative situation, such as the Water Framework Directive in Europe, causing several new restrictions in designing and operating waterways with the purpose of improving the ecological state of the channel systems.
2. *What are the typical properties of the water body to be considered?*
   Is it a lake with low water level changes and deep water? A river with barrages and therefore reduced flow velocities, water level fluctuations, and high water depths in general? Or a free-flowing river with the typical water level fluctuations over several meters and flow velocities generally affecting river bed and banks much more than the ship-generated currents and waves? Or are channels to be considered that are usually heavily modified, e.g. canals with very turbid water? These boundary conditions determine the habitat conditions, together with the bed and bank sediments, and thereby the threatened species.
3. *What are the properties of the fleet?*
   These could be large tows such as on the Mississippi and the Lower Rhine river, modern cargo ships such as on smaller European rivers and channels, or passenger ships on lakes or pleasure boats generally producing larger wave heights than cargo vessels if they are allowed to move very close to the banks. Therefore the most important impact type is highly dependent on the dimensions and type of these ships and also on their propulsion systems, e.g. conventional propellers or jet drives. The combination of fleet and propulsion systems with the system behaviour defines the most important impacts from the technical point of view.
4. *What are the most sensitive areas to be protected against vessel impacts?*
   This could be the channel bed if there are contaminated sediments that should not be resuspended, to mention just one example. Generally it is more likely the bank zone because this is the biologically most productive area of a channel system. The most sensitive areas could also be side channels, back waters, or old waters, which are connected to the main channel if e.g. water level drawdown induces flows and water level changes in these connected areas which are important.
5. *Are the impacts to be considered ecologically relevant?*
   The answer to this question depends e.g. on the state of the ecosystem compared to its natural situation and possible mitigation measures, to mention just two aspects described above in more detail. The ecologically most important impacts are defined by assessing an ecological relevance level together with the sensitive areas and their distance from the fairway, the system behaviour and the fleet to be considered.
6. *What impacts have the most severe effects on the ecosystems and should be reduced?*
   The secondary waves which will be generated mostly by pleasure boats and could cause a destabilisation of the roots of water plants and also of bank sediments by wave stroke. Breaking primary waves which will be generated mostly by cargo vessels moving close to the critical ship speed could cause highly turbulent near-bank flow velocities inside the breaking waves, which displace fish larvae or can destroy bank protections. Return currents are the most important factor in narrow channels, again mostly affecting the aquatic habitat near the bank zone. Propeller-induced flows on the other hand mostly affect the river bed and can lead to scouring, resuspension and increased turbidity. Also the wake flow of a vessel moving downstream

could cause very high flow velocities on the river bed, approaching the ship speed over ground. It could have the same effect as those coming from propulsion systems. The question is: Which measures could be taken to reduce these impacts, if they are ecologically relevant?

7. *Are there mitigation measures available that can be recommended?*
   As mentioned above, these could be indirect measures such as restricted permissions, e.g. concerning ship hull dimensions, maximum engine power or allowed ship speed. In this case measures need to be discussed on how to check if these conditions are met or not, especially concerning ship speed, or the allowed minimum distance from the banks in sensitive areas. This also applies to fairway dimensions and routing in cases in which the fairway depth does not restrict the ship path and so the vessels can move outside the fairway. Therefore mitigation measures also include a policy to ensure the effectiveness of the measures taken. Because the bank zone is generally the most sensitive area of aquatic habitats, alternative bank protection measures, such as willow plantings or palisades instead of revetments, could be a good choice in many cases, especially if wave heights and currents can be restricted up to a certain level. There are no generally valid design rules regarding this point, but the report gives some ideas of cases in which alternative bank protection measures could be used. Mitigation could also mean creating reserves instead of trying to reduce impacts or creating artificial habitats by modified engineering measures in the main channel.

For example, if the sensitive reed zones of lakes are mostly affected by shipping, the corresponding impact will be generated mostly by passenger ships and pleasure boats moving close to the banks and producing high secondary waves, and a changed permission policy, combined with rigid monitoring of ship speed and sailing distances could be the appropriate measure, especially in the case of increasing traffic due to recreational boating, which is a general trend all over the world, and if the fleet modifications consist of boats having longer and deeper draughts. Also measures to make secondary waves break outside the sensitive areas could be appropriate.

Nevertheless, as already mentioned several times in this paper, general recommendations cannot be given for every case, so that recommendations need to be adapted to each specific situation on site. This is the reason why the members of Working Group 27 decided to focus the report mostly on cause and effect relations, such as those shown in the fact files, rather than give detailed recommendations for every possible case.